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Development of Energy Conservation Programs for Commercial Buildings based on Assessed Energy Saving Potentials

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Abstract

Thailand is a developing country whose energy demand is continuously increasing. However, Thailand has limited energy resources, and half of the energy consumed is imported. Buildings account for the largest sector, which shares 53% of total electrical energy consumption in Thailand. Over half of this consumption is due to the large commercial buildings. This study aims to propose energy conservation programs focusing on these large commercial buildings. The energy consumption data were extracted from various sources to develop the building performance models, which were then employed to project its energy consumption for the next 20 years (2030). The analysis shows that the energy consumption from the large commercial buildings in 2030 will nearly double the consumption in the base year (2010) if there is no energy conservation program implemented. However, implementation of the proposed programs of building energy code (BEC) and building energy labeling (BEL) integrated with a rolling plan of the program revision show technically a high potential for savings of electrical energy up to 50% from the total consumption in 2030. Implementation of a program for high efficiency stove and burner can help save additional LPG for cooking and fuel oil for water heating 40% from the total fuel demand in 2030.

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Keywords : Building energy code, Building energy labeling, Energy efficiency, Energy conservation program

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Nomenclature

BAU	business as usual
BEC	building energy code
BEL	building energy labelling
DSM	demand side management
EGAT	electricity generating authority of Thailand
ESCO	energy service company
GHG	green house gas emission
HEPS	higher energy performance standard
LNG	liquefied natural gas
MEA	metropolitan electricity authority
MEPS	minimum energy performance standards
OPEC	organization of petroleum exporting countries
OTTV	overall thermal transfer value
PDP	power development plan
PEA	provincial electricity authority
RTTV	roof thermal transfer value
ZEB	net zero energy buildings level

1. INTRODUCTION

Energy is a crucial factor for driving the country's economy as well as improving people's quality of life. Since the end of the country's economic crisis in 2000, Thailand has consumed increasingly more electricity with a rate of about 4.5% in each year corresponding with its economic growth. In Thailand, buildings from both commercial and residential sectors possess the largest share at 53% of the total electrical energy consumption. More than half of the consumption is due to large commercial buildings. It is expected that the electricity demand from the buildings will increase substantially in the next 20 years. Regarding the country's Power Development Plan (PDP) 2010, Thailand may have to import almost 20% of its electricity in 2030 from 3% at the present.

The Energy Conservation Promotion Act (ECP Act) of Thailand was promulgated in 1992. Ministerial regulations of building energy code (BEC) for large commercial buildings and a fund created to support energy conservation activities (ENCON Fund) became operational in 1995. The BEC set the minimum performance requirements with which the three main systems of all existing designated buildings (i.e. building envelope, electric lighting system and air-conditioning system) must comply. The experience gained, the strong points and the weaknesses in the code implementation were described in [1].

After a long period of the enforcement, the code was revised with a financial support from Danish International Development Agency (DANIDA) and later through funding from the ENCON Fund in order to strengthen its requirements to be suited with the current technologies for buildings already improved. The revised code was already fully implemented in 2010 to new buildings with floor area exceeding 2,000 m2. The buildings that do not comply with the code are not allowed for construction.

Although the BEC has been implemented mandatorily in Thailand for nearly two decades, there is still no voluntary program of building energy labeling (BEL) implemented complementarily to further promote the higher energy efficient buildings in accordance with the concept of mandatory push & promotion pull mechanism (Fig. 1).

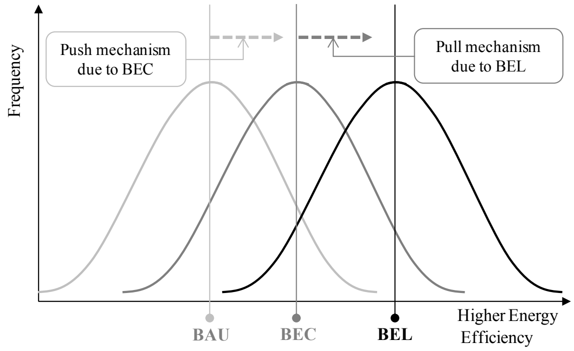

Fig. 1. Push & Pull mechanism concept for energy conservation in buildings.

Regarding the concept, BEC ensures all the buildings comply with the minimum energy standards; low energy efficient buildings are all eliminated eventually. The purpose of BEL is to serve, recognize and encourage the best energy efficient practices beyond the existing BEC.

This paper aims mainly to propose a rolling plan of energy conservation programs for large commercial buildings in Thailand. An estimation of the energy consumption from the buildings was made for a scheme with no implementation of energy conservation programs or business as usual case (BAU). The same analysis was also performed for other cases in which the implementation of energy conservation programs had been decided. The analysis adopted the performance indicators and the energy equation used in BEC to estimate the energy consumption of different building types (i.e. office, hotel, department store, etc.). The average energy performances of each building type were derived from the database of energy audit reports of 1,900 buildings provided by Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy. It is concluded that potential energy saving benefits for large commercial buildings are substantial from the energy conservation program implementation. The decrease in greenhouse gas emissions from energy conservation programs is assessed as well.

2. SYSTEM PERFORMANCE INDICATORS OF THE THAI BEC

This section briefly describes the indicators used to evaluate the energy performance of building systems in the Thai BEC. The background concept of the use of energy equation to calculate the annual energy consumption of a building is also described. More details relevant to the code are available in [1].

The current code (or the revised code) still adopts performance indicators to evaluate the three major building systems, but its values are now enabled for calculating annual energy consumption of a building when its detailed plans are given. The code distinguishes three different times and durations of use of different categories of commercial buildings:

(1) daytime or office pattern,
(2) late daytime to nighttime or department store or restaurant pattern, and
(3) day and night or hotel pattern.

Table 1 lists commercial buildings identified to fall into each category of usage and gives the number of hours of use of each category.

Table 1. Usage duration and total hours per year of three categories of buildings.

Building Category	Usage time	Number of hours per year
Office and school	8.00-17.00	2,340
Department store, hypermarket, and miscellaneous	10.00-22.00	4,380
Hotel, hospital, condominium, and hostel	24 hours	8,760

Regarding the separation of the building category, the minimum performance requirements are also distinguished for the building systems.

2.1. Building envelope

In the Thai code, the Overall Thermal Transfer Value (OTTV) is used as a measure of annual average heat gain through building envelope as sensed by the cooling coil of the air-conditioning system of a building of a given category. It is meant to be used in the equation:

Annual average cooling coil load (of an air-conditioning system)
= (OTTV)(wall area) : as external factor of load
+ lighting, equipment, occupants, and ventilation : as internal factor of load.

It is enabled to calculate the annual energy use in a given building through the relationship:

Annual energy use of a space
= (annual cooling coil load of the space)/COP
+ annual direct energy use by lighting and other equipment,
where COP is the coefficient of performance of the air-conditioning system.

With the above concept, the performance of wall, lighting and air-conditioning can relate to the annual energy consumption of the whole building.

The minimum requirement of building envelope was set based on the life cycle costing principle. Life-cycle costing accounts for initial cost, energy cost, other operating and maintenance cost (including labor), life of each component forming the system; discount rate, inflation and escalation of some cost items such as energy cost, and salvage value of each component when its life is expired. The first two items dominate in our consideration.

To develop the building envelope requirements, thermal properties and life cycle costs of different wall types were compiled and presented to a panel of experts and stakeholders comprising building designers and developers. A series of consultations led to adoption of minimum performance figures for the envelope of each building category shown in Table 2.

Table 2. Minimum allowable energy performance for building envelope.

Building category	Requirement on OTTV and RTTV (W/m^2)
Wall (OTTV)	
Office and school	< 50
Department store, hypermarket, and miscellaneous	< 40
Hotel, hospital, condominium, and hostel	< 30
Roof (RTTV)	
Office and school	< 15
Department store, hypermarket, and miscellaneous	< 12
Hotel, hospital, condominium, and hostel	< 10

2.2. Lighting system

The code recognizes different lighting requirements and specifies three levels of performance requirements. Life cycle costing was applied to show that higher performance level for lighting led to lower power density requirement and lower life cycle cost. Table 3 shows the recommended allowable value of lighting power density (LPD) for each building category.

Table 3. Allowable rated power density for lighting.

Building category	Allowable rated power (W/m^2 of utilized area)
Office and school	14
Department store, hypermarket, and miscellaneous	18
Hotels, hospitals, condominium, and hostel	12

2.3. Air-conditioning system

The same concept was applied to air-conditioning system. For a large air-conditioning system, the main equipment that consumes 65% of power is the chiller. Minimum allowable values for coefficient of performance (COP) of large electric chillers vary from 2.7 for small air-cooled chillers to 5.67 for large water-cooled chillers. For unitary air-conditioners, requirement on coefficient of performance is made for each set.

For a large air-conditioning system, maximum allowable value of rated power of the air-handling system, condenser water cooling system, and chilled water transport system taken together is 0.5 kW/TR.

2.4. Evaluation of annual energy consumption of a building

Equation 1 exhibits the relationship between the building system performance indicators and its annual electrical energy consumption. The first summation in the expression above accounts for rated air-conditioning energy for a year, and the second summation accounts for the energy consumed directly at rated level by lighting and other equipment. In the equation, EQD stands for equipment power density. OCCU and VENT stand respectively for density of occupancy and ventilation rate.

$$
\begin{aligned}
E_{pa} \;=\; & \sum_{\substack{i=1 \\ i\neq j}}^{n} \Bigg[\frac{A_{wi}\left(OTTV_i\right)}{COP_i} + \frac{A_{ri}\left(RTTV_i\right)}{COP_i} \\
& + A_i \left\{ \frac{C_l\left(LPD_i\right) + C_e\left(EQD_i\right) + 130C_o\left(OCCU_i\right) + 24C_v\left(VENT_i\right)}{COP_i} \right\} \Bigg] n_h \\
& + \sum_{i=1}^{n} A_i (LPD_i + EQD_i) n_h
\end{aligned}
\qquad (1)
$$

The summation includes all air-conditioned zones and unconditioned spaces, and accounts for the corresponding area of each space. No air-conditioning energy is contributed from unconditioned spaces. The values of coefficients of thermal power contribution to the load of the air-conditioning systems by lighting, equipment, occupants and ventilation: C_l, C_e, C_o, and C_v are given in Table 4. The energy requirements of a building account for energy use during the nominal operating hour, n_h, of the given building category only and each is given in Table 1.

Table 4. Values of coefficients of thermal power contribution of each type of building.

Building category	C_l	C_e	C_o	C_v
Office and school Department store, hypermarket, and miscellaneous	0.84	0.85	0.90	0.90
Hotel, hospital, condominium, and hostel	1.0	1.0	1.0	1.0

3. ENERGY CONSERVATION PROGRAMS FOR BUILDINGS

In this study, five levels or scenarios of building energy performance were established to portray the energy consumption trends of buildings for the next 20 years. The meaning of each of the performance levels is described as follows.

- ***Base level (BASE)*** This is the average level of energy performance of the existing building stock. The values of system performance indices in this scenario are obtained from a data base of energy audit reports of DEDE. The resultant annual energy consumption of 219 kWh.m^{-2}.Y^{-1} falls within expected level for an office with the given proportion of air-conditioned space.
- ***Building energy code level (CODE)*** For this level, energy performance of all systems equal exactly to those required by the Thai BEC and equipment of normal performance, same performance as those of the reference scenario, are used. The resultant annual energy consumption of 175 kWh. m^{-2}.Y^{-1} meets minimum performance level of Thai BEC.
- ***Higher energy performance standard level (HEPS)*** This is the performance level that should be recommended to the building developers. The systems would possess lower LCC than those of the BEC case, but by no means correspond to the upper limits of efficiency of each system. The resultant annual energy consumption reaches 141 kWh.m^{-2}.Y^{-1}, that is about two thirds of that of the reference case.
- ***Economic level (ECON)*** This is the level that is still economical and achievable by using conventional technologies and domestic construction. This scenario may offer lower life cycle costs when technologies for building design and construction improves in the near future, say at 5 years from present. The resultant annual energy consumption reaches 82 kWh.m^{-2}.Y^{-1}, which is about one third of that of the reference case.
- ***Net zero energy buildings level (NZEB)*** At this level, new low-energy technologies, some promising but are not commercially available, are employed. System performance levels are all higher than those at the ECON level. For these building types, on-site electricity production from PV cells almost meets the demand of the whole buildings. This is the imaginary zero energy building created by using mathematical model. Energy consumption in this scenario is 55 kWh.m^{-2}.Y^{-1}. But when electricity from the roof top PV is accounted, the net consumption is 27 kWh.m^{-2}.Y^{-1}. Net zero energy buildings have been built for demonstration in many countries including Australia, China, Malaysia, and Singapore.

A zero energy building (ZEB) or net zero energy building is a general term applied to a building that has net zero energy consumption and zero carbon emissions annually. The development of modern net zero-energy buildings will become possible through the progress made in new construction technologies and techniques and academic research. Within the present time, it is expected that zero energy buildings are not yet cost effective.

The entire world is now racing to reduce carbon emission to meet the 450 ppm goal. The target is global sustainability. Zero energy buildings feature strongly in the sustainability scene. Although zero energy buildings are constructed for demonstration in Malaysia and Singapore, which are under climates similar to that of Thailand, the demonstration buildings in the two countries are very specific and their designs cannot be replicated in other commercial buildings. Further rigorous research is needed to develop technologies that can be widely replicated. Thailand has the opportunity to contribute to world sustainability by providing technical services to countries with similar climate if Thailand develops such sustainable technologies and provides such services globally.

Table 5 details the values of the system performance indicators and its corresponding LCC for the office case at five energy performance scenarios. The system performance indicators for eight building categories for five energy performance scenarios are summarized in Table 6.

Table 5. Performance of building systems and other parameter values for office building for five energy performance levels.

System or Equipment	BASE	CODE	HEPS	ECON	NZEB
Building Envelope					
OTTV	61.4	50	30	20	15
RTTV	29.1	15	15	12	10
LCC of wall ($B.m^{-2}$ $wall.Y^{-1}$)	288	274	252	230	?
Air-conditioning					
System COP ($kW.RFT^{-1}$)	2.21 (1.59)	3.13 (1.12)	3.64 (0.97)	4.42 (0.8)	5.98 (0.59)
LCC ($B.m^{-2}$ $floor.Y^{-1}$)	321	304	291	296	?
Lighting					
LPD in air-conditioned area (Wm^{-2})	20	14	9	6	1
LCC ($B.m^{-2}$ $floor.Y^{-1}$)	160	140	80	58	?
LPD in un-condtioned space (Wm^{-2})	10	8	6	4	1
Equipment					
EQD in air-conditioned area (Wm^{-2})	45	45	45	25	20
EQD in un-condtioned space (Wm^{-2})	10	10	10	5	4
Occupancy					
Load from occupant (Wm^{-2})	10	10	10	10	10
Ventilation ($l.m^{-2}.s^{-1}$)	0.75	0.75	0.75	0.5	0.5
Night and off hours security					
Light (Wm^{-2})	2	2	2	1	1
Equipment (Wm^{-2})	1	1	1	0.8	0.8
Number of normal office hours	2340	2340	2340	2340	2340
Number of outside hours	6425	6425	6425	6425	6425
Building energy consumption ($kWh.m^{-2}.Y^{-1}$)	219	175	141	82	55
LCC of 3 systems	769	718	623	584	?

Table 6. Values of the system performance indicators of different building types and different performance scenario.

Items	BASE	CODE	HEPS	ECON	NZEB
OTTV (Wm^{-2})					
Office	61.4	50	30	20	15
Hotel	33	30	15	10	7.5
Hospital	35.5	30	15	10	7.5
Department store	43.6	40	25	15	10
School	61.1	50	30	20	15
Condominium	33	30	15	10	7.5
Hypermarket	43.6	40	25	15	10
Misc	57.4	40	25	15	10

Table 6. Values of the system performance indicators of different building types and different performance scenario (con't).

Items	BASE	CODE	HEPS	ECON	NZEB
OTTV (Wm^{-2})					
Office	61.4	50	30	20	15
Hotel	33	30	15	10	7.5
Hospital	35.5	30	15	10	7.5
Department store	43.6	40	25	15	10
School	61.1	50	30	20	15
Condominium	33	30	15	10	7.5
Hypermarket	43.6	40	25	15	10
Misc	57.4	40	25	15	10
Lighting system (Wm^{-2})					
Office	22.7	14	9	6	1
Hotel	16.2	12	8	5	4
Hospital	13.7	12	8	5	4
Department store	19.6	18	12	8	6
School	14.6	14	9	6	2
Condominium	16.2	12	8	5	4
Hypermarket	19.6	18	12	8	6
Misc	19.6	18	12	8	6
Equipment power density (Wm^{-2})					
Office	45	45	45	25	20
Hotel	35	35	35	30	25
Hospital	12	12	12	10	8
Department store	26.2	26.2	26.2	20	15
School	25	25	25	20	15
Condominium	40	40	40	30	25
Hypermarket	45	45	45	25	20
Misc	20	20	20	15	12
Air Conditioners, COP ($kW.RFT^{-1}$)					
All building types	2.21(1.59)	3.13(1.12)	3.64(0.97)	4.42(0.80)	6.00(0.59)

4. ASSESSMENT OF POTENTIAL ENERGY CONSUMPTION AND SAVINGS

This section intends to illustrate the energy consumption and its technical saving potential at micro level (individual building) and at macro level (the target buildings in the building sector), annually and cumulatively at some future years.

The methodology used for assessment of potential savings at macro level is as follows. Relevant data from an energy audit database for each type of and each size of commercial buildings is extracted. The data are then used to find values of parameters relevant to energy use for lighting, air-conditioning, and other end-uses of each building type and each size. These parameters are used to either form a building model of each building type and size, or are used to adjust other parameters so that each building model possesses features that are consistent with the values of these parameters. The resulting models are called base case or reference models. The OTTV, RTTV, LPD and COP of each base case model are then changed to comply with those required by BEC. The annual energy (kWh) by each model using code complying parameter values are now obtained as if these are energy values of a code complying building. This is called the "CODE" case. We also use our prior experience to change OTTV, RTTV, and other parameters to higher performance levels, using present technologies commercially available that together offer life cycle cost that are considered to be near minimum for each given building type. These cases are called the "HEPS" and "ECON" cases.

We also calculate energy and power demand savings of the code complying case and of the economic cases for each type and size of building. We identify the number and size of very large buildings from the energy audit database. From data obtained from the power distribution utilities, we identify energy consumption of each type of very large commercial buildings, and that of each type of large commercial buildings. We assume the year 2010 as the year that all buildings must comply with BEC. We consider five scenarios of energy savings, the code case and the promotion cases. We calculate annual savings and cumulative savings for all scenarios based on energy conservation program for year 2030, where the latter case is the last year of the present power development planning period (applicable from 2007).

Reference [3] describes a similar attempt at estimating energy saving potential from implementation of Hong Kong Energy Code. The methodology used in [3] is based on the use of information from enquiries made to building managements and walk-through surveys. Energy savings are estimated mainly from improvement of efficiency at equipment level. The paper also includes estimation of emission reduction from reduced power generation requirement.

4.1. Energy consumption trends of the base case

a) Electricity

The electricity consumption data in 2002-2009 from MEA and in 2002-2007 from PEA were used to predict the average growth rate of the electricity demand in 2010-2030. Figure 2 illustrates the predicted energy consumption trends of buildings. The electricity consumption from both new buildings and existing buildings were generated on the assumption that there is no any government intervention.

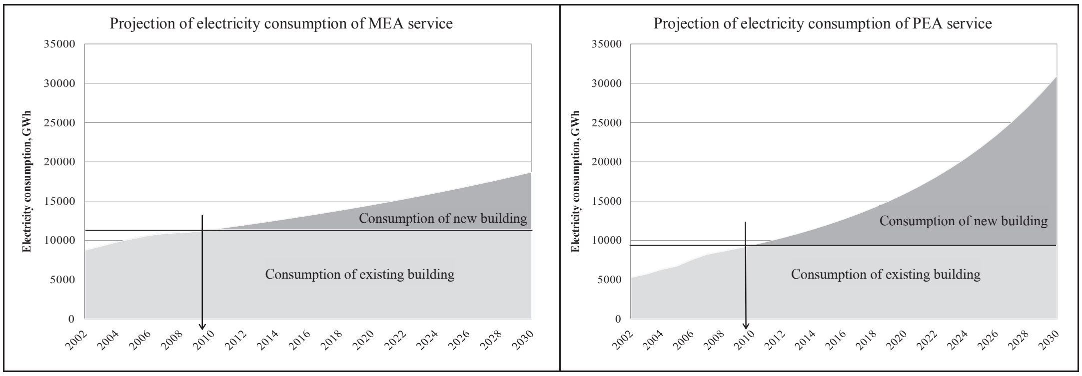

Fig. 2. Prediction of commercial buildings electricity consumption of BAU.

b) Fuel

Two main types of fuel used in commercial buildings are LPG for cooking and fuel oil for water heating. In this study, LGP consumption of each building type were available but not for the case of fuel oil [4]. Thus, in Table 7, the consumption of fuel oil is presented in lump sum of all buildings. Figure 3 illustrates the predicted trend of LPG and fuel oil consumptions of the buildings.

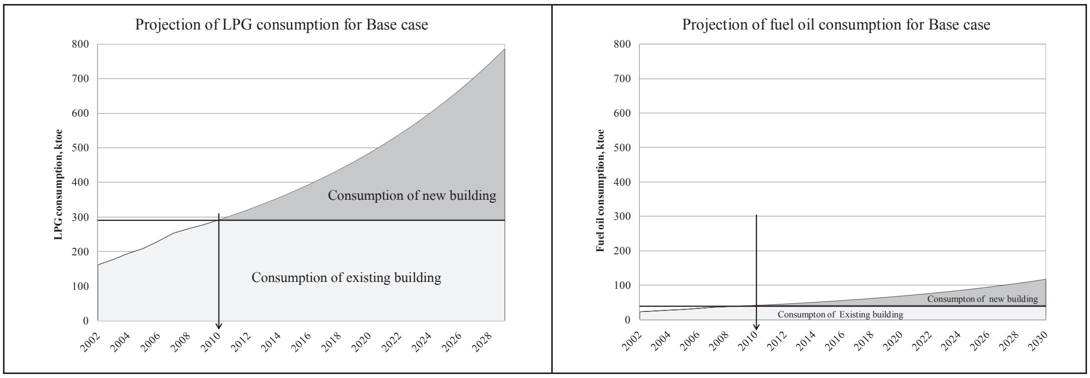

Fig. 3. Prediction of fuel consumption for Base case.

Table 7. Fuel consumption of commercial building in 2030 in the Base case.

Building type	**Electricity (GWh)**		**Fuel (ktoe)**	
	MEA	**PEA**	**LPG**	**Fuel Oil**
Office	8,020	3,191	76	-
Hotel	660	2,605	102	-
Hospital	1,392	538	21	-
Department store	804	12,142	184	-
School	1,021	1,142	17	-
Condominium	995	7,471	48	-
Hyper Market	4,942	2,425	376	-
Miscellaneous	860	1,497	7	-
All type of buildings	-	-	-	118
Total	18,693	31,011	949	118
	49,704		1,067	

4.2. Energy consumption trends for high energy efficiency cases (CODE, HEPS, ECON, NZEB)

a) Electricity

With the performance indicators presented in Table 6, the annual electrical energy consumption for each of the buildings can be determined using energy equation of the BEC. The analysis results are shown in Table 8. Figure 4 illustrates the comparison of the electrical energy consumption of the higher energy efficiency buildings in percentage term based on its corresponding building in base case.

Table 8. Annual electrical energy consumption (kWh.m^{-2}.Y^{-1}) of the buildings for the five performance levels.

Building type	BASE	CODE	HEPS	ECON	NZEB
Office	219.2	170.5	140.6	81.7	57.3
Hotel	271.2	199.0	159.9	116.4	96.8
Hospital	244.1	194.7	168.3	114.6	81.1
Dept Store	308.3	231.1	194.3	146.4	111.8
School	102.2	85.0	72.3	58.0	39.1
Condominium	256.3	211.2	197.9	132.3	95.3
Hyper Market	370.0	298.0	265.5	160.6	126.4
Other	182.1	133.8	109.5	66.2	52.9

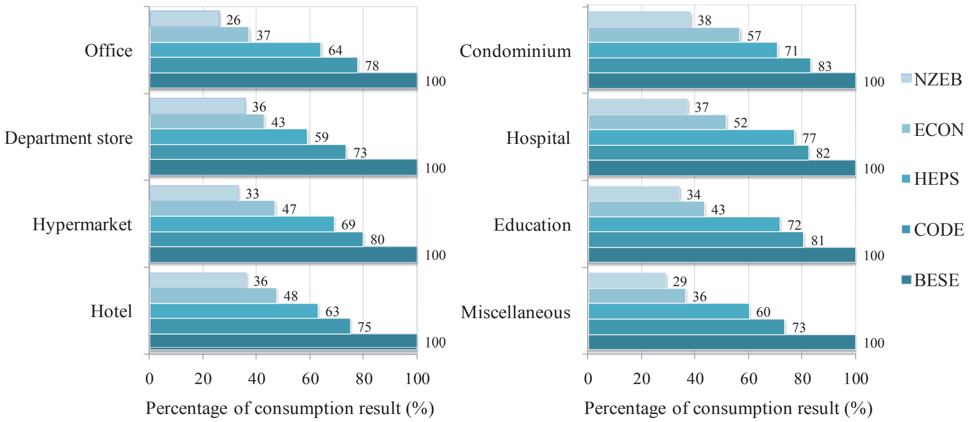

Fig. 4. Reduction of the energy consumption of higher energy efficiency buildings comparing to the base case buildings.

The electrical energy consumption reduction of the higher energy efficiency buildings is then used to project its consumption trend for the next 20 years as shown in Fig.5.

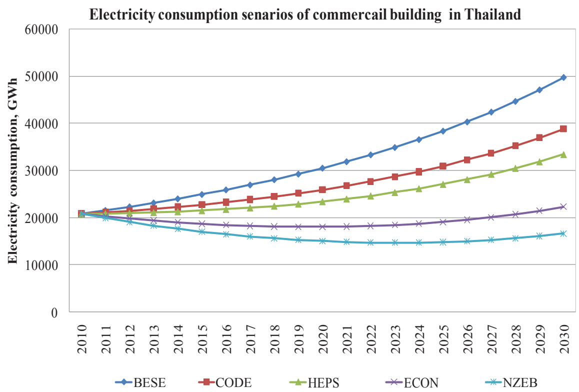

Fig. 5. Energy consumption of the case study.

In this study, it is assumed next that both BEC and BEL are both implemented in Thailand. A rolling plan is also carried out for code and energy label revision every three years. The procedure is adopted in practice in various countries. As shown in Table 5, building energy label would comprise with 5 energy performance levels. The performance of Label No.2 corresponds to the mandatory BEC requirements whilst that of Label No.5 represents the highest energy performance level of the building at that time. The terms "CODE", "HEPS", "ECON" and "NZEB" in Table 9 are referred to the performance levels as described in Table 6. The performance level of "CODE+" is laid between that of "CODE" and "HEPS" and so on. It can be observed from Table 5 that the mandatory BEC requirements will be strengthen from "CODE" in 1st period to "CODE+" in 2nd period.

Table 9. A rolling plan for revision of building energy code and building energy label.

1st period	2nd period	3rd period	4th period	5th period	6th period	7th period
No.2 = CODE »	**CODE+ »**	**HEPS »**	**HEPS+ »**	**EEON »**	**ECON+ »**	**NZEB = No.2**
No.3 = CODE+ »	**HEPS »**	**HEPS+ »**	**EEON »**	**ECON+ »**	**NZEB**	
No.4 = HEPS »	**HEPS+ »**	**EEON »**	**ECON+ »**	**NZEB**		
No.5 = HEPS+ »	**EEON »**	**ECON+ »**	**NZEB**			
EEON »	ECON+ »	NZEB				
ECON+ »	NZEB					
NZEB						

Remark: 1st period: year 2011-2013; 2nd period: year 2014-2015; 3rd period: year 2017-2019; 4th period: year 2020-2022; 5th period: year 2023-2025; 6th period: year 2026-2028; 7th period: year 2029-2030

According to the rolling plan mentioned above, we analyze next the energy consumption trends for three cases:

- Base case: There is no implementation of any energy conservation programs
- Only BEC: Only BEC is implemented
- BEC & BEL: Both BEC and BEL are implemented.

The analysis result is illustrated in Fig. 6.

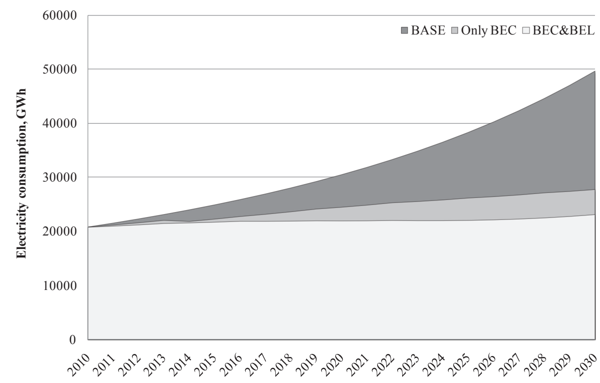

Fig. 6. The energy consumption trends of (1) *Base case*: No implementation of any energy conservation programs (2) *Only BEC*: Only BEC is implemented (3) *BEC & BEL*: Both BEC and BEL are implemented.

b) Fuel

To predict the LPG and fuel oil consumptions for the next 20 years, the efficiency of the burner in Table 10 is employed. The base case assumes that the burner with average performance are still used in all building. The high efficiency case assumes that the burner with high efficiency are used in all new buildings and the low efficiency burners in existing buildings are replaced 10% each year with the high efficient one. The fuel consumptions of the two cases are shown in Fig. 7.

Table 10. Performance of burner.

Burner Type	Average performance (Base)	High efficiency performance (HEP)
LPG	49%	58%
Fuel oil	80%	95%

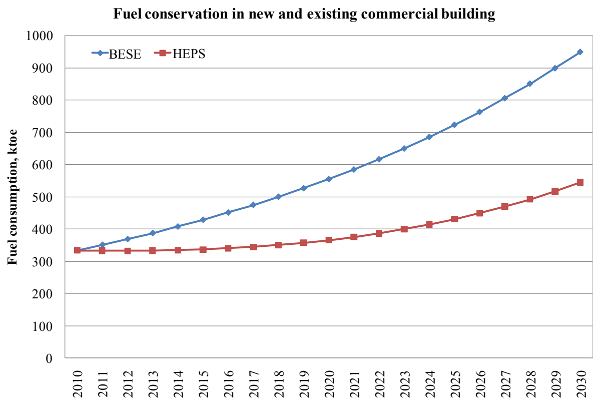

Fig. 7. Prediction of fuel consumptions of commercial building in Thailand.

Table 11 summarizes the total electrical energy saving and fuel saving from large commercial buildings in 2030 when BEC and BEL and high efficiency program for burner are implemented.

Table 11. Fuel consumption of commercial building in 2030 in the case of energy conservation programs.

Building type	**Electricity (GWh)**	**Fuel (ktoe)**	
		LPG	**Fuel Oil**
All type of buildings	23,160	477	67
Total	23,160	544	

4.3. Energy Saving and GHG reduction

The energy saving from energy conservation program for a large commercial building also leads to the GHG emission mitigation. The GHG emission factors [5, 6] and Thailand fuel generation mix of electricity generation in 2030 [7] were used as the reference to estimate GHG reduction from energy building conservation program. The summary of the saving potentials and GHG reduction are reported in Table 12.

Table 12. Saving potential and greenhouse gas emission decrease in 2030.

Energy Type	Consumption in 2030 (BASE case)	Consumption in 2030 (Energy Conservation Program)	Energy Saving		GHG reduction in 2030				
					CO_2 (kton)	CH_4 (ton)	N_2O (ton)	NO_X (ton)	CO (ton)
Electricity (GWh)	49,704	23,160	2,6544	47%	2,318	112	80	24,691	2,237
LPG (ktoe)	831	477	354	43%	279	16	71	1,124	154
Fuel oil (ktoe)	118	67	51	57%	43	6	1.2	406	30
Total					**2,640**	**134**	**152**	**26,221**	**2,421**

5. CONCLUSIONS

This paper proposes the energy conservation programs for large commercial buildings in Thailand. The savings from electrical energy and fuel including the GHG reduction are assessed. With the intensive implementation of BEC and BEL, electricity and fuel consumption of the large commercial buildings can decrease more than 50% and 40% in the year 2030, respectively. This warrants the significance of the BEC and BEL implementation in Thailand.

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